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FLEET RETROFIT REPORT

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Foreword

This Fleet Retrofit Report is submitted in accordance with
Task XIV of the Statement of Work of NASA contract No. NAS2-7208.

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I. INTRODUCTION AND SUMMARY

This report was completed as part of United Air Lines' work under contract to NASA to evaluate and flight test an avionics system which aids the pilot in making two-segment approaches for noise abatement.

The scope of this report, as defined by the contract, is to discuss the implications of equipping United's fleet of Boeing 727-200 aircraft with two-segment avionics for use down to Category II weather operating minima. United presently operates a fleet of 28 "stretched 727's." Possible expansion of this fleet in the future is discussed in this report, but unless otherwise noted, estimates refer to the 28 aircraft fleet.

Differences between United's and other airlines' equipment or operations are pointed out where such are deemed important. These discussions are not intended to be complete, but they serve as examples of the limitations of some of the statements and assumptions herein and therefore as warnings against application of the results beyond the scope of the report.

At the time this report was written, United had the experience of incorporating two-segment approach avionics systems on two different aircraft. One belonged to Ansett Airlines of Australia and was used, under lease, for the out-of-revenue-service portions of the evaluation. The other is the United aircraft which is presently in use as the in-revenue-service evaluation aircraft of the two-segment approach system. This report is based upon the experience of the design, installation, and operation of these systems.

The cost of installing dual two-segment approach systems is estimated to be \$37,015 per aircraft, including parts, labor, and spares. This is based on the assumption that incremental out-of-service and training costs could be minimized by incorporating the system at airframe overhaul cycle and including training in regular recurrent training. Accelerating the modification schedule could add up to 50 percent to the modification costs. Recurring costs of maintenance of the installation are estimated to be of about the same magnitude as the potential recurrent financial benefits due to fuel savings.

I. INTRODUCTION AND SUMMARY

The submittal of this report should not be construed as indicating that United Air Lines has determined that two-segment approaches have been proven acceptable for operations to Category II or any other weather minima, nor that United Air Lines intends to implement any of the policies or procedures referred to or implied in this report. This report will be incorporated into the final report on the evaluation program to be issued at a later date. Analyses and results reported herein may be revised at that time to reflect new findings either from the continuing evaluation or additional analysis of the program to date.

II. INSTALLATION

PHILOSOPHY OF INCORPORATION

Existing Aircraft

The installation of two-segment approach systems is a modification of major magnitude. The installation completed on the UAL aircraft in the evaluation program involved approximately seven days of out-of-service time ("down time"). However, this installation was carried out on a prototype basis, and included a data recording installation of considerable magnitude although installed basically in parallel with the actual two-segment systems. On a production basis, it is estimated that the installation would involve approximately 200 manhours. This is equal to 25 manshifts. Accessibility to confined areas is a major constraint to consider in planning the duration required for such an installation. It is doubtful that more than two men at a time could be planned to work on such a project on the average. This implies a minimum of four to five days out-of-service to complete the installation, including a post-modification test flight.

There are a number of ways modification projects of this size can be accomplished. The most cost effective is to coordinate the work with major overhaul cycles of the aircraft. Two other means which can be considered are segmenting the installation such that the work can be performed during maintenance checks or scheduling a "special route" for having the aircraft out-of-service. These latter two methods would incorporate accomplishment during overhaul for aircraft scheduled for regular overhaul during the expected project duration.

Overhaul - The present limit on Time Between Overhauls (TBO) for United's 727's is 16,000 airframe hours. This is approximately 76 months based on the current utilization rate. Such overhauls can take from one to three weeks duration based on manpower scheduling. The current average is about two weeks; the minimum possible is five days.

The advantage of installing a system such as this during the planned overhaul schedule is that it does not involve an increment in aircraft out-of-service costs. The aggravation of accessibility problems due to the high density of work would probably preclude being able to perform such an installation in a minimum duration overhaul visit; however, minimum duration overhaul visits are generally not contemplated for United's aircraft due to the manpower requirement fluctuations implied by such scheduling. Test flying of the system could be incorporated into the normal post-overhaul test flight.

II. INSTALLATION

Overhaul - Continued

The major disadvantage of this approach is the time period required to equip the entire fleet. As mentioned above, the present limit implies a cycle of over 6 years and this is increased as experience and sampling allow longer TBO. The presently anticipated TBO extension schedule for United's 727's is as follows:

<u>DATE</u>	<u>TBO</u>
Today	16000 hrs
Feb., 1974	18000 hrs
Feb., 1975	20000 hrs
Dec., 1975	22000 hrs
Nov., 1976	24000 hrs
Oct., 1977	25000 hrs (probable ultimate limit)

System incorporation coordinated with airframe overhauls therefore implies project completion for the fleet as much as ten years after the first aircraft in the fleet is modified. The rate of incorporation would be essentially constant throughout this period.

Maintenance Checks - Maintenance checks, which involve 24 hours of aircraft out-of-service time, are currently limited to 2200 operating hours (approximately 314 days). A maximum limit of 2800 hours is anticipated by October, 1974, which implies approximately annual maintenance visits of this magnitude.

A number of considerations make this alternative unattractive for the installation of two-segment approach systems. First, additional engineering and planning effort is required to segment the work, and additional installation manpower is required due to added access and close up needs. Secondly, there would probably be some parts of the project which could not be segmented into a 24 hour period. Such work would have to be done on a "special route" basis, and the out-of-service time involved, as well as out-of-service time and costs involved in the post-project test flight, would have to be considered.

It is possible that this installation philosophy might shorten the time period required to equip the entire fleet as compared to coordinating with overhauls. (As previously mentioned, if this philosophy were used, some work would still be coordinated with overhauls when possible.) It is doubtful, however, that the period could be shortened to less than five or six years.

II. INSTALLATION

Special Routes - This is the most expeditious and the most expensive means of incorporating new installations on a fleet of aircraft. Such "special routes" are planned to incorporate changes required by FAA in order to meet the deadlines which often accompany such requirements. They are also used for projects which management feels justify the added aircraft out-of-service costs. Of course, as many such projects as are possible to accomplish on a parallel basis are scheduled for a single special route when it is decided that one is required. This has the effect of spreading the added cost among the several projects.

Five days of out-of-service time for 727-200's would cost on the order of \$16,000 based on out-of-service costs typically charged for this type of aircraft. The post-project test flight costs would also have to be considered. Special route projects are not planned in the future, so it is impossible to determine if other projects requiring such scheduling would come along at the same time to allow these costs to be "shared."

The advantage of the special route philosophy of installation is that it reduces the time required to incorporate a modification on an entire fleet of aircraft. In addition, some advantages due to learning curve effects might be realized by being able to limit the number of personnel working on such a project. If one "production line" were established, the project could very likely be completed on the 28 B-727-200's in less than a year. However, if additional aircraft were involved in the same or similar modification program, this time could increase significantly because parallel special route production lines for additional aircraft types would not be possible due to facilities limitations. For instance, a special route involving five days per aircraft may take two or three years for all 150 UAL 727's.

Other Airlines - The above assumes the particular aircraft maintenance program which is presently used by United Air Lines. Each airline has a unique maintenance program, subject to FAA approval. The adaptability of the various programs to the requirements of special modifications is impossible

II. INSTALLATION

Other Airlines - Continued

to predict on a general basis. The Boeing Company publishes a bi-monthly report "Airline Maintenance Inspection Intervals" (Document number D6-26100) which details the programs used by all the operators of Boeing aircraft. Similar information is available from the Air Transport Association and probably the other airframe manufacturers as well. An example of the variability of such programs is that different airlines presently have time between major overhaul limits on B-727's anywhere from 8,000 to 16,000 hours, the average being about 12,000.

Follow-On Aircraft

Of the narrow-bodied aircraft types in United's present fleet, the B-727-200 is the most likely to grow in the future. If a commitment to have two-segment approach systems installed is made far enough in advance of aircraft delivery, it is best to incorporate the system during manufacture, which is done by means of including the requirement in the detailed specification of the aircraft. It has been found, however, that if such decisions are not made until the last 9 to 12 months or less prior to delivery, it is often cost effective to accomplish the modification as a "pre-service project," installing the equipment after delivery but before the aircraft is put into revenue service. This, of course, represents out-of-service time as in the case of a special route for aircraft already in service, but the change of having several projects among which to share the costs is somewhat greater.

It is difficult to predict what the cost will be if the system is incorporated during aircraft manufacture. The cost inevitably increases, however, as the decision to include an added system is delayed, until as mentioned above, it becomes cost effective for the airline rather than the manufacturer to do the modification.

Fleet Incorporation Time Period

The project durations discussed above (10 years for overhaul, 5 to 6 for maintenance checks, etc.) refer to the time from the first aircraft installation to fleet completion. The time between project go-ahead to first installation must be added to these figures. This time can be affected by existence of an industry standard, equipment availability, and engineering and planning personnel workloads and priorities. These considerations might add a year or more to the total time duration of the entire modification program.

II. INSTALLATION

INSTALLATION DESIGN

Among the minimum equipment requirements for Category II landing operations is a requirement for either a single flight director with dual displays and a single automatic approach coupler, or two independent flight director systems. (United's aircraft are equipped with two fully independent flight director systems and an autopilot automatic ILS approach coupler.) It is apparent that dual two-segment approach systems would probably be required to meet the intent of the minimum requirements for Category II operations. Even if not required, United Air Lines would probably install dual systems to meet operational and dispatchability requirements. So although single systems were installed on the evaluation aircraft, the estimates throughout this report are based on dual installations. In such a dual installation one system would interface with the Captain's flight director and the autopilot, and the second would interface with the First Officer's flight director.

A number of changes are required to the aircraft's existing equipment complement in order to install the two-segment approach systems. This is an area where wide divergence between various airlines exists. The differences between the two evaluation aircraft are mentioned by way of example in the following list of major changes required to existing systems.

Flight Director

The Ansett aircraft had Collins FD108 equipment, which did not include glide slope indication on the Attitude Director Indicator (ADI). The modification to add this indication was not necessary on the United aircraft, which had an FD109 system incorporating the ADI glide slope information. It might be necessary to incorporate flight director command bar biasing to some flight director installations and some airlines (and indeed UAL's older B-727's) would require even more extensive flight director modifications.

Distance Measuring Equipment (DME)

The Ansett aircraft had provisions for an ARINC 568⁽¹⁾ digital DME system which were used as the two-segment computer requires a "pulsed pair" output such as is available from the 568 system.

(1) ARINC numbers are designators of Aeronautical Radio, Incorporated "characteristics" which are used as a means of providing various standards for airborne equipment.

II. INSTALLATION

Distance Measuring Equipment (DME) - Continued

United's aircraft was equipped with dual ARINC 521 analog DME's which do not have pulsed pair output available. A modification for 521 systems developed by Collins was installed to provide the required output consistent with that of the 568 interrogator. This modification was used in the evaluation program, and would also be used for a fleet retrofit program.

Auto Throttle/Speed Command

The Ansett aircraft had dual speed command systems and provisions for an auto throttle system which were utilized. It was determined in the evaluation that auto throttles were not necessary on this type of aircraft for making two-segment approaches. On a fleetwide basis, no such systems would be contemplated based on the evaluation results to date.

Altimetry

The two-segment computer presently accepts only DC altimetry signals: either barometrically corrected altitude or pressure altitude and a baro-set correction signal. This presents a problem as most electrical altimetry information available on aircraft is coarse-fine synchro rather than DC. There are several means to provide the computer with the information in the required form. On both evaluation aircraft an altimeter was installed in the cockpit which was driven by the standard synchro output of air data computers and incorporating an electrical baro-corrected DC output. This, however, is a non-standard installation which would not be acceptable on a fleet-wide basis.

For purposes of this report, it is assumed that the two-segment computer would be modified to accept the standard (ARINC 545 or 565) coarse-fine synchro altitude signal. If this capability is not incorporated by two-segment equipment manufacturers, the retrofitting of two-segment systems on existing aircraft will be unacceptable; although some existing air data computers can easily be modified to provide the non-standard output, for many computers a complete redesign would be required.

II. INSTALLATION

Altimetry - Continued

For dual systems, a second electrical altimetry source would be required for UAL aircraft since they are equipped with only single air data computers. The required modifications in this area would be as follows:

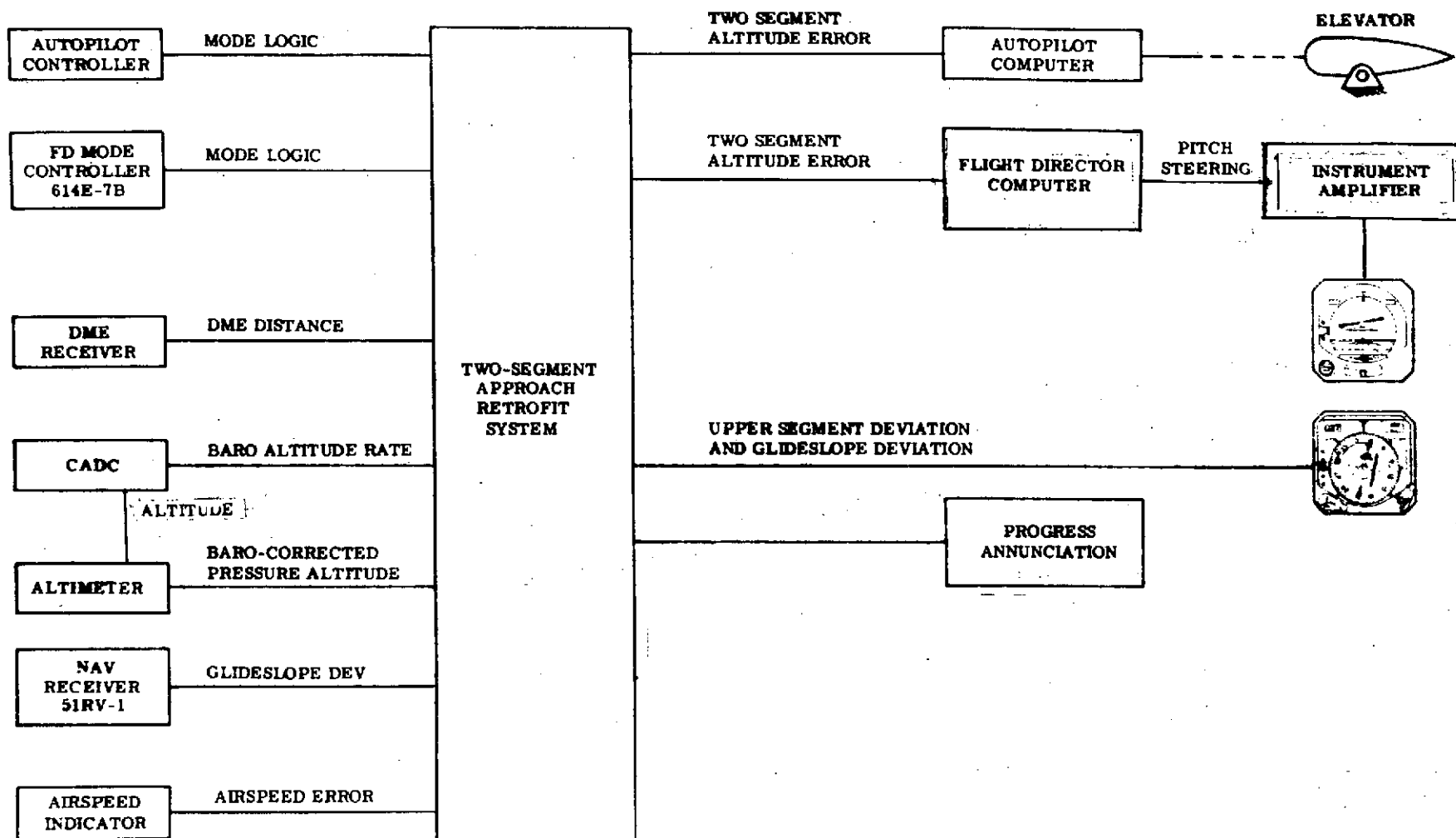
1. One added altitude sensor, conforming to air data computer specifications, but containing only those components needed for altitude.
2. Modification of existing air data computers to provide an additional coarse-fine synchro output.
3. Modification of altimeters to provide output of baro-set information.

It should be noted that this is not the most likely way in which the altimetry needs of two-segment equipment would be met by United Air Lines. A number of possible demands for change in the air data systems are foreseen in the coming years. Among these are increased accuracy for reduced vertical separation, standardization to millibars as the pressure setting units, and providing altitude signals for RNAV, altitude alert, and other needs. Such demands have led to the consideration of an all-inclusive updating of the altimetry system, presently estimated to cost approximately \$20,000 per aircraft (ref UAL report F-1635). If the all-inclusive updating is undertaken, the two-segment approach installation would share in the cost with the other requirements.

The estimates in Section V of this report are based on the three altimetry modifications listed above. If the all-inclusive approach was made, the costs assignable to the two-segment might be somewhat less.

Wiring

The incorporation of two-segment approach equipment involves extensive interface wiring revisions and additions (see simplified interface diagram on following page). On the evaluation aircraft these changes were incorporated by means of T-connectors. This method makes installation and demodification significantly easier than if existing aircraft connectors are used and wiring is spliced where needed. It is, however, only suitable on a semi-permanent basis and actual aircraft installations would have to be incorporated by the more permanent methods of splicing and revising existing connectors.



TYPICAL AIRCRAFT/TWO-SEGMENT APPROACH SYSTEM INTERFACE
(SINGLE SYSTEM SHOWN)

II. INSTALLATION

EQUIPMENT DESIGN

Dual two-segment approach systems include two computers, two switching units, & one airport elevation input panel with isolated dual outputs. Cost estimates for this equipment have, previously, assumed equipment similar to that being used in the evaluation aircraft. There are, however, a few changes to that equipment considered essential to make it compatible with the airline operational environment.

As mentioned above, the computer should be revised to accept coarse-fine synchro altitude information. The implications of a DC potentiometer altitude signal requirement given existing altimetry systems are simply not acceptable. The requirement for the computer to accept coarse-fine synchro signals increases the computer cost approximately 20 percent; the pricing herein assumes this modification.

The computer and/or switching unit should also incorporate Built-In-Test-Equipment (BITE). The test set used in the engineering evaluation program proved helpful in troubleshooting problems, but its use is not considered feasible for normal line operations. BITE can, of course, be as simple or as complex as is desired. For the system to be viable in day-to-day airline service, it must include a first level of functional self-test. Initial indications are that BITE to provide 60 percent confidence level troubleshooting would add 15 to 20 percent to the cost of the computer; this, however, would probably not be enough to meet the airlines' needs. The capital cost of BITE capability is weighed not only against the capital cost of test sets for line maintenance stations, but also the recurring expense of more lengthy and complex tests and the many intangible costs caused by departure delays which can be expected with a special test equipment type of operation. Since the BITE requirements have not been defined sufficiently to date, the costs of such requirements are not included in the present equipment cost estimates.

A number of other changes to the equipment would probably be requested before United Air Lines would consider its installation. Such changes would be based in part on the experience gained in the present on-line evaluation program. These will be detailed in the final report, but possible items in this category include deletion of auto-disengagement of the system on glide slope due to invalid DME information (provided a suitable alternate means for autopilot gain programming can be found), and changing the re-engagement procedure requirements when disengagement occurs on upper segment. Tracking accuracies between dual systems must also be reviewed to determine their operation acceptability. Another change which would be necessary is proper interface for Automatic Test Equipment (ATE) for back-shop maintenance of the equipment. The cost of such changes is not considered herein, since the exact requirements for such changes have not yet been defined.

III. OPERATIONS

FLIGHT PERSONNEL QUALIFICATION

During the first three months of the on-line evaluation, 26 line captains were qualified for making two-segment approaches. Two methods were used to qualify these captains; some were given an audio-visual presentation, a detailed briefing, and an enroute check by a previously qualified pilot, others were given a training session in a flight simulator in addition to the above.

Initial on-line evaluation experience indicates that pilots previously qualified in B-727 equipment can satisfactorily execute two-segment approaches in line service without a simulator session. It is suggested that those not previously qualified in B-727's could be qualified for two-segment approaches in the simulator during their initial B-727 transition training.

A pilot training and proficiency program incorporating both ground and flight training is specified for Category II operators in FAA Advisory Circular 120-29. Components specified therein include:

- Both Pilots-in-Command and Seconds-in-Command must be provided training
- Ground training curricula covering both ground and airborne systems
- Items to be covered in initial and recurrent proficiency checks
- Flight training requirements, including substitutability of flight simulator training for flight training

If two segment approaches were to be made to Category II, training would have to fit within the guidelines of the advisory circular.

Since equipment installation would occur over a period of time as described in Section II, little benefit could be derived by scheduling special training sessions to accelerate the qualification of pilots to operate two-segment equipment. A practical means of qualifying pilots therefore appears to be to incorporate the two-segment approach into the present curricula of recurrent pilot training. This could be done with insignificant initial investment and incremental recurrent costs, compared to the cost of the actual aircraft installations.

III. OPERATIONS

FLEET BUILD-UP

Regardless of which method described in Section II is used to incorporate two-segment equipment on the aircraft, incorporation would be totally random amongst the fleet, and the routing of those aircraft after incorporation would likewise be random. During the period of time when part of the fleet had been modified and part of the crews were qualified to operate the equipment, matching the crews with the aircraft to make two-segment approaches would be impossible. In general, therefore, the probability of having a crew qualified to make two-segment approaches flying an aircraft so equipped would be the fraction of B-727 crews qualified times the fraction of the fleet equipped.

In addition to the effect the means of incorporation has on the duration of fleet retrofit, the rate at which co-located DME stations are installed will certainly have an effect on speed with which two-segment approaches are implemented in airline service.

IV. SUPPORT OF OPERATIONS

SPARES

Spare line replaceable units are allocated among the various Line Maintenance stations in consideration of the number of stations served and the frequency of station visits by aircraft carrying the particular units, the predicted or experienced equipment reliability, and the effect a unit failure has on the dispatchability of the aircraft. In addition, the total fleet spares complement is based on consideration of predicted or experienced turn around time for the equipment (i.e., the time from equipment removal from the aircraft to return to the spares supply as a serviceable unit), and on spare parts pooling agreements with other airlines.

Based on past experience of similar units, the spare requirements for dual two-segment approach systems would be 20 percent for computers and 10 percent for the switching units and airport elevation panels.

The modification of the DME transceivers (as discussed in Section II) presents another problem often confronted in retrofit programs which involve interfaces with existing systems. United uses the same model DME interrogator on all DC-8's except DC-8-62's, all B-727's, and all B-737's. Modification of a portion of the units for use on one fleet or sub-fleet (e.g., B-727-200 in this situation) implies an impact on the total number of spare units required. It is often cost effective to modify all the units involved, even if only part of them would make use of the modification, as long as the modification does not effect the normal operation of the unit (one way interchangeability) which is true in the case of the subject DME "pulsed pair output" modification.⁽²⁾ This is particularly true when considering units used on B-727's, which are also used on other fleets, since the B-727's serve so many stations and the spares implications due to the requirement for non-standard units are significant.

In this particular case, the two approaches to this problem are nearly equal, both implying more than \$6,500 per aircraft installation in spares burden for DME units alone, due to a \$250 per unit modification! (Based on 750 units requiring modification to keep them all standard vs. 35 new spares required if the B-727-200 DME's were made non-standard.) We feel, however, that it is

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- (2) In general, it is found that, where the modification cost is small compared to the new unit cost, it is cost effective to modify only a portion of the units if the ratio of unmodified units to new spares required is greater than the ratio of the spare unit cost to the modification cost.

IV. SUPPORT OF OPERATIONS

unrealistic to assume that two-segment approach systems (and therefore the subject DME modification) would be installed on only one sub-fleet of aircraft. If all the B-727's were being modified for two-segment approaches, it would be cost effective to modify all the DME interrogators and the per aircraft assigned cost of the DME modification, including spares, would be \$1250 (about a 150 percent spares burden). If all B-727's and B-737's were being modified this would be reduced to \$850 (70 percent). For purposes of this report, the latter assumption is used.

The altimetry modifications present several different situations with respect to spares requirements. The added altitude sensor would be a new unit, requiring the stocking of new spares. The air data computer modifications must be made to all the B-727-200 air data computers. (These units are unique to B-727-200's so an interchangeability problem similar to that posed by the DME modification does not occur.)

The altimeter modification to provide a baro-set signal from the Captain's altimeter would make that altimeter interchangeable with an instrument presently used on the B-737. No spares would have to be modified. There are 77 First Officer's altimeters requiring the added baro output, including 41 spares and the units used on four DC-8's.

The air data computers have 60 percent spares which would require modification. The similarity of the altitude sensor to the air data computer implies that 60 percent spares would be required for the sensor also.

It should again be pointed out that this analysis does not represent the most likely means by which altimetry requirements of two-segment would be met, but is the best way a cost of meeting those requirements can be estimated.

LINE MAINTENANCE TRAINING AND PROCEDURES

Approximately one-third of United's Radio and Electronic (R&E) Mechanic personnel are trained and qualified in the service and maintenance of Category II equipment. The mechanic training program is an integral part of the Category II maintenance program specified in Advisory Circular 120-29. Annual refresher training is required to maintain qualification. Training in the maintenance of the two-segment approach components of a Category II system could be incorporated into this recurrent training without significant incremental costs.

IV. SUPPORT OF OPERATIONS

Likewise, the reliability reporting and maintenance procedures components of the maintenance program could be expanded to incorporate the two-segment equipment. As with all aircraft systems, removal, installation, and functional and operational checking procedures would be detailed in the basic mechanic reference document, the "MM/OV" (Maintenance and Overhaul Manual).

Line maintenance servicing opportunities are typically only one-half to one hour long. The test set used during the evaluation program would therefore not be practical for normal day-to-day line operations. The scope of the tests using the test set is that of an overhaul level operational check of the systems; a functional check implemented by means of built-in test equipment should be sufficient at the Line Maintenance level to determine the Category II serviceability of the system. (This judgement, of course, would be subject to approval by the FAA.)

V. COSTS

INITIAL COSTS

Sections II through IV preceding provide the background for the estimates herein. The initial and recurring costs of both flight crew qualification and line maintenance training are assumed to be negligible on an incremental basis (above that presently required for Category II operations) compared to the cost of the actual installation. It is likewise assumed that installation could be coordinated with the regular overhaul cycle of the aircraft, thereby alleviating the need to consider incremental aircraft out-of-service costs.

The per aircraft cost estimates of dual two-segment approach systems on United's B-727-200's are given in tabular form on the following page. For the 28 aircraft fleet, the cost would total about \$1,036,420. Any large scale expenditure in flight equipment such as this would be capitalized over the remaining expected life of the aircraft on which it is installed.

OTHER COST CONSIDERATIONS

It is extremely difficult to determine what the costs to maintain equipment such as the two-segment approach system might be in actual service. Anywhere from 5 percent to 10 percent of the equipment cost might be expended annually in the service and maintenance of avionics systems. If 7.5 percent is used, the dual two-segment approach installation would cost on the order of \$1700 per year to maintain.

The operation of two-segment equipment can also yield financial benefit in the form of fuel savings due to the lower thrust levels used during the approach. A two-segment approach with a 4000 ft. upper intercept altitude can save about 125 pounds of fuel compared to a standard ILS approach, based on the data from several approaches flown during the off-line evaluation. If five approaches a day are assumed, and 50 percent of the approaches attain the average savings mentioned above, the savings would amount to about \$1850 per year per aircraft (based on 13¢ per gallon fuel cost).

It therefore appears that the recurring costs and recurring financial benefits are of the same order of magnitude, and for purposes of this analysis can be assumed to cancel each other out. It should be noted, however, that the initial maintenance costs would probably be higher, decreasing with experience and equipment maturity, while the initial fuel savings would be smaller, growing with added opportunities to make two-segment approaches.

ESTIMATED B-727-200 RETROFIT COSTS

DUAL TWO-SEGMENT APPROACH SYSTEM

(Per Aircraft Costs, Based on 28 A/C Fleet)

	<u>Labor</u>	<u>Material & Equipment</u>	<u>Spares</u>
Two-Segment Avionics	\$ -	\$15,800	\$2,690
DME Modifications	200	300	350
Altimetry Modifications	300	5,700	3,375
Wiring Harnesses, Connectors	2,000	1,500	-
Approach Progress Display, Switch, Misc.	400	100	-
Installation	4,000	-	-
Engineering	<u>300</u>	<u>-</u>	<u>-</u>
TOTALS	\$7,200	\$23,400	\$6,415

NOTES: Engineering costs prorated among 28 aircraft.

Labor costs estimated at \$20 per manhour fully allocated.

Installation assumed to occur at regular overhaul cycle, and training incorporated into existing recurrent curricula minimizing incremental costs.

Avionics costs include proration of non-recurring costs to provide coarse-fine synchro altitude input capability. Estimates based on Collins Radio Company budgetary estimates for 150 dual systems, on the basis that systems would not be installed only on a sub-fleet of aircraft. Equipment prices are extremely quantity sensitive.

REFERENCES

NASA Contract NAS2-7208 Statement of Work, "Evaluation and Flight Test of Avionic Systems for Noise Abatement Approach" dated 9/13/72.

FAA Advisory Circular 120-29, "Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators" dated 9/25/70 (as revised 12/15/71 and 7/26/72).

The Boeing Company, "Airline Maintenance Inspection Intervals" (Document D6-26100).

United Air Lines Engineering Report F-1635, "Air Data System Planning - B-727" by O. E. E. Anderson, dated 4/26/73.